Experimental Evaluation of Alternative Low Damage Solutions for Reinforced Concrete Walls

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QuakeCoRE NZ Centre for Earthquake Resilience

QuakeCoRE Annual Meeting
4 – 6 September 2017, Wairakei Resort, Taupo

University of Nevada, Reno

THE UNIVERSITY OF AUCKLAND Te Whare Wānanga o Tāmaki Makaurau NEW ZEALAND

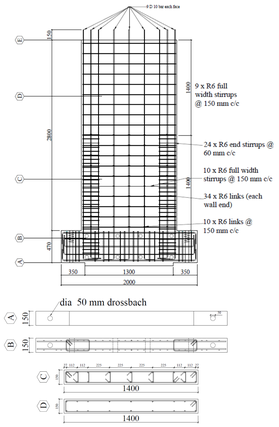
OVERVIEW

Four half-scale concrete walls with different low damage solutions are currently being tested at the University of Auckland, New Zealand. Low damage alternatives were selected based on literature review and discussion with industry professionals. The first wall has debonded reinforcement encased in steel tubing extended into the foundation, which is intended to trigger a crack at the wall base and distribute the reinforcement strain across the debonded length. In the second wall, steel fiber-reinforced concrete is substituted for conventional concrete throughout the wall, which should allow for increased tensile strain hardening and confinement, but is expected to be lesser when compared to ECC. In the third and fourth wall, ECC is substituted for conventional concrete in the plastic hinge region, which will increase the tensile capacity of the wall and delay deterioration in the hinge region. Higher axial load will be applied to the fourth wall relative to the third to observe the impact fibers have on confinement.

OBJECTIVES

1. Comparatively evaluate the performance of various lower damage solutions.
2. Assess reparability of modified walls compared to conventional walls.
3. Formulate recommendations for future construction practices.

Benchmark Concrete Wall Design



- ✓ Minimally reinforced concrete wall
  - Design in accordance with: NZS 3101:2006 (Amendment 3 draft)
  - 1.4 m x 0.15 m in plan, 2.8 m tall

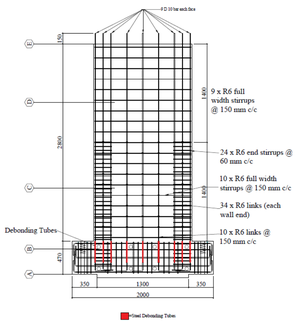
Benchmark Wall		
Shear Span Ratio		2
Axial Load Ratio		3.5%
Shear Demand to Capacity Ratio		0.52
Vertical Reinforcement Ratio (%)	End Zone	1.0%
	Web Zone	0.465%
	Total	0.673%
End Zone Reinforcement		4 D10
End Zone Length (mm)		210
Horizontal Reinforcement Ratio (%)		0.25%
End Ties & Spacing (mm)		R6@60
Web Ties & Spacing (mm)		D10@150

Low Damage Solutions

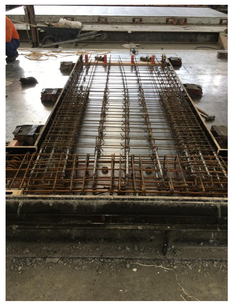
1. Debonded Reinforcement

- Location of Debonding: Foundation
- Length of Tube: 300mm
- Material of Tube: Grade 400E Steel
- Thickness of Tube: 3mm

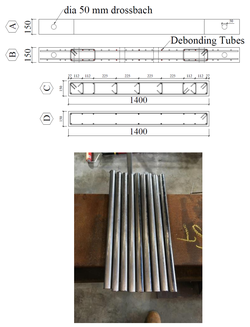
Potential Benefits
- Reduced strain localization
- Delayed bar buckling and fracture
- Crack localization (limit to single crack for easy repair)



Close up of debonded tubes in the foundation.



Debonded reinforcement wall in formwork.



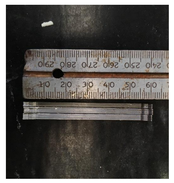
Steel debonding tubes.

2. Fiber Reinforced Concrete

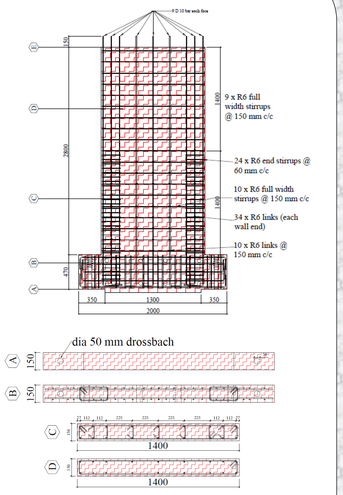
- Steel hook fibers
- 80kg of fibers per 1m^3 of concrete
- 3.33% fibers by weight

Potential Benefits
- Increased tensile strength
- Increased crack propagation

Profile view of a steel fiber.



Plan view of multiple steel fibers.



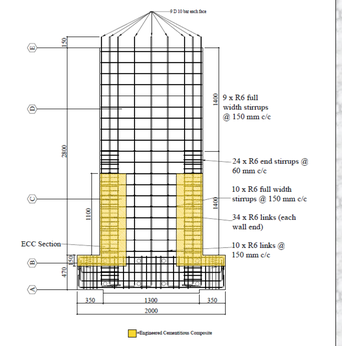
3&4. Engineered Cementitious Composites (ECC) within plastic hinge

- Wall 3: Benchmark Axial Load
- Wall 4: High Axial Load
- ECC has Polyvinyl alcohol fibers at 2% by volume

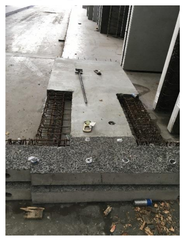
ECC Section Dimensions
- Above Foundation: 1.1m x 0.363m x 0.15m
- Inside Foundation: 0.15m x 0.636m x 0.15m

Potential Benefits
- Increased tensile strength and ductility
- Increased crack propagation
- Delayed deterioration
- Self confining

Testing on these walls still in progress.

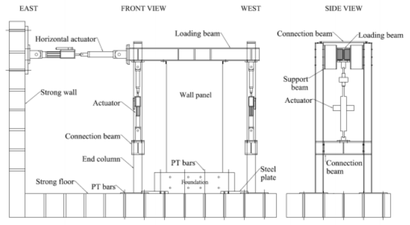


Formwork for ECC sections.

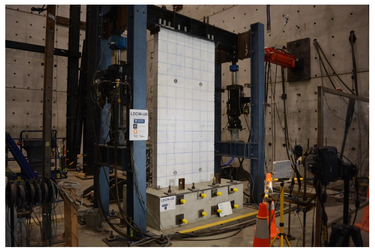


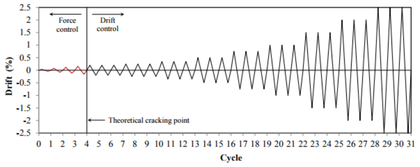
ECC wall after pouring of conventional concrete.

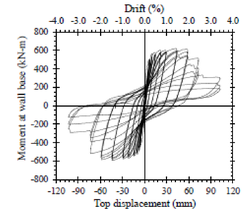
Test Setup & Loading Protocol



(a) Test setup illustration



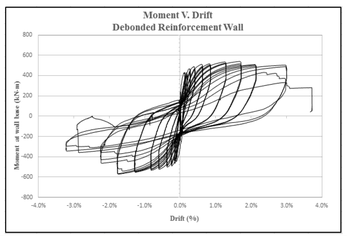


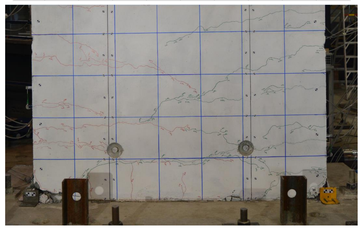


Moment V. Drift
Benchmark Wall

Results

Debonded Reinforcement

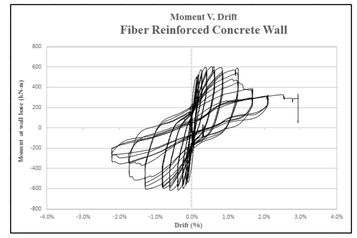


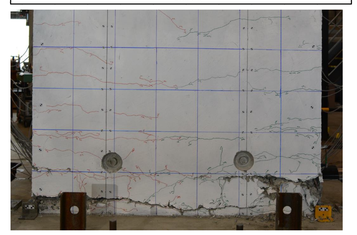


Base crack at 2.5% drift (cycle 29.00).

Observations
- Base crack opened at 0.25% drift
- Crack localization at 1.0% drift
- Bar buckling at 2.0% drift
- Bar fracture 2.0% drift
- Debonding tube buckled

Fiber Reinforced Concrete





Base crack at 2.5% drift (cycle 29.00).

Observations
- Base crack opened at 0.25% drift
- Crack localization at 0.75% drift
- Bar buckling at 1.0% drift
- Bar fracture at 1.5% drift
- Fibers pulled out